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Ensuring the Reliability of Functioning of Non-Addressed Fire Alarm

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Abstract

One of the ways that is aimed at reducing losses from fires is to detect a fire at the initial stage of its occurrence, which can be most effectively carried out only with the help of fire automation systems. The latter includes information and measurement systems (IMS) of fire alarm systems, which are part of the fire detectors. Fire alarms (FA) are triggered by the appearance of primary signs of fire, transmitting a signal to the fire alarm control and indicating equipment (FACIE) through the appropriate loop. The FACIE processes these signals and forms commands for further actions, for example, sending alarm signals (sound and/or light) by fire alarms to warn people of danger, transmitting alarm notifications to the fire station and/or centralized fire monitoring console, as well as enabling and/or disabling certain equipment or engineering systems (including fire protection systems). Fire alarm loops (FAL) are electrical circuits that connect the output links of the FA, which include auxiliary remote radio elements and conductors, and are intended not only for issuing notifications about their status to the FACIE, but also for supplying power to these detectors. The reliability of the functioning of such IMS directly depends on the correct choice, according to the appropriate methods, of the nominal value of auxiliary hinged elements of loops, problems that arise during the use of equipment from different manufacturers.

Keywords: Detection, Fire, System, Standard, Resistor, Current, Nomogram, Calculation Algorithm.

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1. Introduction

Requirements for the use of fire alarm systems (FAS) are regulated by many regulatory and technical documents. Thus, in clause 1.6 of the national standard DSTU EN 54-1: 2014 [1] is a requirement for compatibility of FA and FACIE: “a component of the system meets the requirements of the relevant part of EN 54, does not mean that such a component will necessarily function correctly in conjunction with another component that also meets the requirements of the relevant part of EN 54 (for example, the FACIE in combination with the FA), unless both components have been evaluated together as meeting the requirements for the system.” In addition, in accordance with paragraph 7.2.1 of the DBN.2.5-56:2014 [2], FAS must detect signs of fire at an early stage and not give false positives, and this also depends on the balance of the FAS with the FACIE which is carried out at the appropriate ratings of the final, limiting and shunt resistors.

Each of the manufacturers of FACIE and FA in the technical documentation provides their own methods and recommendations for determining the values of mounted elements of FAL. In practice, it is not always possible to immediately achieve a balance between FAL and FACIE. The value calculated according to the method provided in the documentation for FACIE may differ from the required resistance rating if the FA in the FAL is used by other manufacturers. This is explained by clause 1.6 of the national standard DSTU EN 54-1: 2014 and the fact that

modern FA are active elements of the AMS, which do not have the same volt-ampere characteristics. Given the above, the question arose in the development of methods of determination of denomination of external FAL components on various types of FA and brands of conventional fire alarm control panels, and this requires first of all the preliminary establishment of possible modes of operation of the control panels of different manufacturers and principles the initialization of all the functional states of the FAL with the subsequent receipt of relevant laws. The obtained regularity will become the basis for the conclusion of the necessary conditions for the approval of fire alarm components and the calculation of the nominal value of mounted elements of FAL. The purpose of the study is to develop a method of calculating the elements of the loop of the fire alarm system based on components from different manufacturers.

2. Analysis of recent research and publications

All non-address FACIE determine the state of the FAL by measuring the total resistance of the connected loop with the FA installed in it and the final element [3-5]. These states of the FAL and the device itself are displayed on the led indicators of the FACIE. In the FACIE “Tiras-4P”, in the event of power problems, the "Fault" and "Power" indicators flash (extended power failure indication is also provided) [12-16]. Faults are shown by flashing zones (Fig. 1).

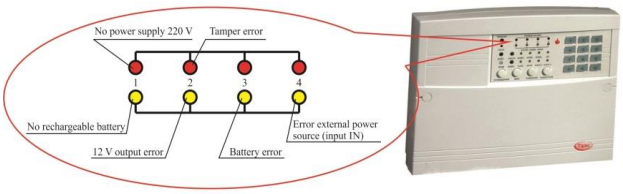

Figure 1. Extended power failure indication FACIE "Tiras-4P"

Lines of FAL of a typical non-addressed fire alarm control and indicating equipment (Fig. 2) are connected to its contact devices.

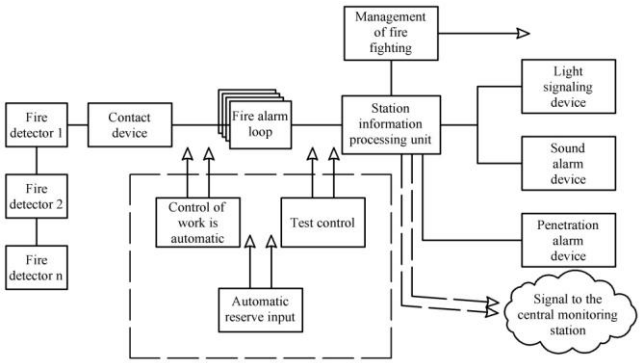

Figure 1. Generalized block diagram of a non-address fire alarm system

In the general station information processing unit, blocks of fire alarm loops are connected, in which information from the fire detectors is processed. In general station information processing unit performs communication functions between other blocks and a number of functions that are common to all fire alarm loops sends control signals to light signaling devices, sound signaling devices, penetration alarm devices, and management of firefighting. In case of triggering the FA or their failure, the station information processing unit generates and transmits the corresponding signal over the communication line to the central monitoring station.

The test control unit and the automatic control unit check the operation of the station in the corresponding modes. The units are powered via the automatic reserve input unit from the main or backup power supply.

3. Material and method

The main requirements for the FACIE of fire alarm system:

- control of several alarm loops with any types of fire detectors (passive – for opening and closing the signal circuit; active – powered by the loop; manual);
- autonomous operation from the built-in backup power for 24 hours in standby mode and 3 hours in “Fire” mode;
- enabling notification devices (sirens) powered by backup power;
- activation of automatic fire extinguishing and smoke removal equipment or activation of ventilation by means of a built-in relay;
- transmission of the “Fire” and “Malfunction” signals to the central monitoring station (CMS);
- operation in automatic mode without operator participation.

Conventional fire alarm control panels, if necessary, can carry out a re-examination of the zone triggers. It is used to eliminate false positives arising from the influence of electromagnetic interference, electrostatic discharges and other phenomena, after which the ability of the FA to restore standby mode as a result of reset is preserved. After the FA is triggered in the zone, FACIE performs the automatic reset procedure, without switching to the mode “Fire”. If the zone is not reactivated again during the time interval from the first operation specified in parameter [11] (programmed separately), FACIE remains in the “On – call” mode, otherwise it switches to the “Fire” mode. The algorithm for this function is shown in figure 3.

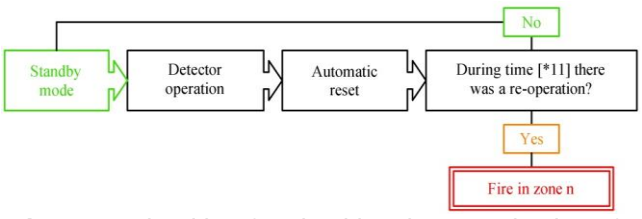

Figure 3. Algorithm for checking the re-activation of the FA

The conditions for the formation of the corresponding modes of operation of the FACIE are different for each manufacturer and depend on the design features of the device. For the reaction of the FA to the appearance of primary signs of fire, they can be divided into two groups: normally closed and normally open. Detectors are connected to the FACIE using two-wire or four-wire circuits [6-11]. The most widely used two-wire scheme. Detectors with normally-closed contacts are connected in series to the dropper loop (see Fig. 4).

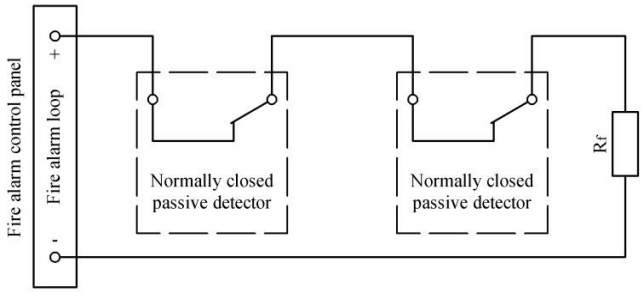

Figure 2. Wiring diagram for normally-locked FA in a two-wire loop R_f – final resistor

In standby mode, the loop is energized and a certain current flows through it, which is usually called the standby one. During the operation of one or more detectors, the next current instantly drops to zero, which is a sign of a fire. This method of determining whether the detector is triggered has a significant drawback: the breakage of the loop is perceived as a fire. Breaking the loop completely disables the system. To eliminate this disadvantage, use loops with shunt (bypass) resistors (Fig. 5), which is installed in parallel to the output contacts of each normally closed FA.

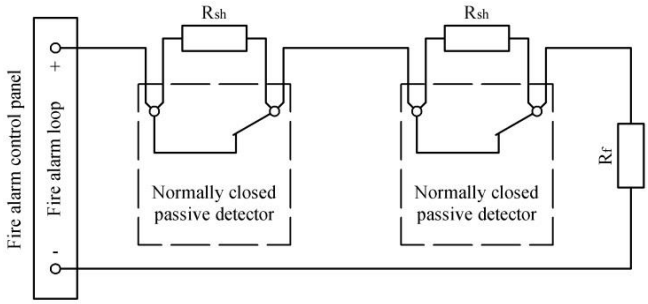

Figure 3. Circuit for connecting normally-locked FA with a shunt resistor to a two-wire loop R_{sh} – shunt resistor; R_f – final resistor

In standby mode, the current value is determined by the resistance of the end element or end device, since the resistance of the detector contacts is significantly less than the resistance of the shunt resistor, the current passes through the FA contacts. If the detector is triggered, its contacts open and current begins to flow through the shunt resistor. As a result, its value is reduced by increasing the total resistance of the FAL. By the amount of current reduction, you can determine not only the fact that the detector is triggered, but also the number of detectors that are triggered in the loop. During a loop break, the current drops to zero. This connection diagram (see figure 5) allows you to identify faults such as line breaks and short circuits. The principle of operation of each FA and the input resistance in various operating modes is indicated in its technical data sheet. Passive FA with normally-open contacts are connected to the dropper loop in parallel (see Fig. 6).

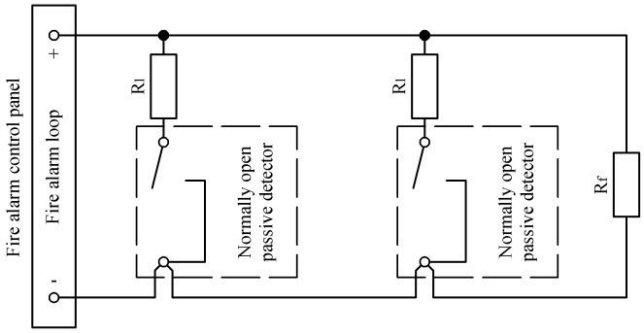

Figure 4. Wiring diagram for normally open FA in a two-wire loop R_l – load resistor; R_f – final resistor

In this scheme, a load resistor R_l is installed sequentially to each FA. If the detector is triggered, its contacts are closed, and current begins to flow through the closed contacts and the resistor R_l. As a result, the current in the loop changes, which is defined by the FACIE as a «Fire» signal.

4. Results

After analyzing the table of states of the FACIE "Tiras-4P" [3], it was found that the duty mode of operation is in the range of 2 to 3.7 kOm. For normal operation of the FACIE, the final resistor must not go beyond the set resistance limits, and the fire zone will be triggered when the specified resistance limits are exceeded.

Fig. 7 shows the limit limits of resistances in different operating modes when working with FA, the contacts of which are closed with verification for two sensors.



Figure 5. Nomogram of the FACIE modes when working with detectors with contacts that are closed and verified by two FA

The nomogram shows that the fire notification is received when the FAL resistance is between 0.3 and 1 kOm, and when the value is within 1...2 kOm, verification occurs (Fig. 8). In other words, in order for the alarm signal to be received, it is necessary that two FA in one FAL are triggered. If the resistance is less than 0.3 kOm, the

FACIE gives a signal that the FAL is closed and the “Fault” indicator lights up. In addition, the “Fault” indicator will work if the resistance in the zone is greater than 3.7 kOm, which indicates a break in the loop or the removal of detectors in the zone.



Figure 6. Nomogram modes of FACIE when working with detectors with contacts that are closed without verification for two detectors

Fig. 9 shows a nomogram illustrating the operation of the FACIE and the values of the resistances of the FAL when working with detectors with contacts that open and verify the two detectors.



Figure 7. Nomogram of the FACIE modes when working with detectors with contacts that open and verification by two FA

The trigger for this option is located in the other side, that is, the resistance in the loop increases (verification is in the range of 3.7 to 6.1 kOm, and fire alerts are in the range of 6.1 to 8 kOm). All supports that are larger than the specified ones indicate that the break is triggered. Similarly, as in the previous case, the break mode may indicate a break in the loop, or the removal of the detector on the loop.

The operation of these FA, which operate on the principle of opening contacts, is possible without verification for two detectors (see Fig. 10). Similar nomograms have been obtained in relation to control panels of other manufacturers. Their analysis allowed us to establish that the possible modes of operation of all non-address FACIE of different manufacturers are identical and different in the values of resistances at which the corresponding state of the FAL is established.



Figure 8. Nomogram modes of FACIE when working with detectors with contacts that open without verification for two FA

Therefore, the entire range of resistances that can be accepted by the FAL of non-address FACIA is distributed into three main areas (see Fig. 11): “Alarm 1” – the loop resistance tends to 0; “Standby mode” and “Alarm 2” – the loop resistance tends to ∞. Each of the “alert” areas consists of three subdomains: “attention”, “fire”, and “malfunction”.



Figure 9. States of non-address FACIE depending on the resistance of the FAL

In standby mode, when none of the FA detected any signs of fire, the FACIE actually determines the resistance of the FAL, which should be in the range of R3...R4 (in other words, the nominal value of the terminal resistance must be within the specified limits, and if you go beyond them, you will switch to the “Alarm" mode and trigger the FAS).

The presence of three subdomains of the "alert" mode is explained by the need of the FAS for extended information content of events occurring in the controlled zone. Plumes of non-directional FAS can operate in one of two operating modes – single-threshold or two-threshold. In two-threshold mode, in the case of a single FA in the loop, the FACIE sends a signal “Attention”, which in relation to the FA with normally open contacts should be in the range r2...r3 and in relation to the FA with normally closed contacts – r4...r5. When two FAS are triggered, a “Fire” signal is given, which corresponds to the range r1...r2 for FA with normally open contacts and the range r5...r6 for FA with normally closed contacts. In single-threshold mode, if a single SP is triggered in the plume, the FACIE immediately sends a «fire» signal.

The resulting nomogram (see Fig. 11) is taken as the basis for determining the necessary conditions and the conclusion of the corresponding equations for determining the nominal value of the mounted elements of the FAL, the use of which will ensure the reliability of the FAS. One of the design stages of the FAS is the construction of the FAL, which provides for the selection of mounted elements (resistances), which depends on the properties of the FA and FACIE. The correctness of this choice will ensure the balance of the FAL with the FACIE and the reliability of determining FACIE the state of the FAL. In the case of FA with normally closed contacts, the total resistance of the FAL, in case of their operation, will always be greater than the value of the resistance of the terminal resistor of the loop (see Fig. 4). The equivalent electrical circuit of the FAL with thermal FA1...FA_n is given on fig.12. The value of the final FAL resistor depends on the design properties of a specific model of the FACIE, embedded in it during its design, and ideally (according to Fig. 11) should correspond to the average value of the resistance range of the zone “Standby mode”:

$$R_f = (r3+r4)/2 \quad (1)$$

where r3 i r4– accordingly, the extreme lower and upper limit of the FAL resistance of the “Duty mode” zone.

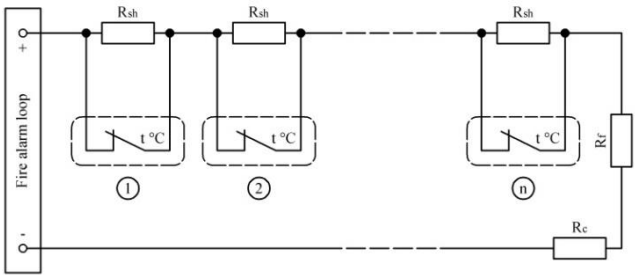

Figure 10. Equivalent electrical circuit of FAL with normally-closed thermal FA R_c – permissible linear resistance of the conductor

Since resistors are produced according to the accepted standard series – in practice their nominal value should be chosen from the nearest value of the series to the calculated one. The maximum allowable linear resistance of R_c FACIE wires depends on the properties of the FACIE and is always indicated in its technical data sheet. The R_{sh} resistance determines the threshold for triggering the FAS and the type of FAL operation mode (single – or two-threshold). In the case of reaching the threshold values of the controlled parameter (in this case – temperature) environment sensitive switching element (thermal overload relay) of the FA opens and as a result- the resistance of the shunt resistor R_{sh2} is added to the total resistance of the FAL. So, the first condition that must be met in the two-threshold mode of FAL operation:

$$r4 < R_{sh2}+R_f + R_c <r5 \quad (2)$$

Further, the verification by two FA, to the total resistance of FAL, is added, the resistance of the shunt resistor of the second FA and accordingly must be executed in the second condition:

$$r5 < 2R_{sh2} + R_f + R_c < r6 \quad (3)$$

So, the maximum allowable linear resistance of R_c of FAL conductors is a fairly small value (according to the technical data sheets [3-5] of various manufacturers of the FACIE of the order of 0.2...0.25 kOm), and the FAL resistance in the corresponding state of the FACIE must be in the average value of this range, then inequality (2) and (3) can be simplified and go to the equation for determining the nominal R_{sh} of the shunt resistance. The value of the shunt resistance corresponds to the two-threshold mode of operation of the FAL FAS, which can be determined from the following dependence:

$$R_{sh2} + R_f = (r4+r5)/2 \quad (4)$$

Consequently:

$$R_{sh2}=[(r4+r5)/2]-R_f \quad (5)$$

The calculated value of the R_{sh} of the shunt resistance according to (5) must then be reduced to a normal series of resistances, and the resulting value must be checked for compliance with conditions (2) and (3). The value of the shunt resistance R_{sh1} corresponds to the single-threshold mode of operation of the FAL FAS, determined from the following dependence:

$$R_{sh1} + R_f =(r4+r6)/2 \quad (6)$$

Consequently:

$$R_{sh1} = [(r4+r6)/2]-R_f \quad (7)$$

The calculated value of R_{sh1} of the shunt resistance according to (7) in the future should be brought to a normal series of resistances, and the resulting value should be checked by fulfilling the following condition:

$$r4 < R_{sh1} + R_f + R_c < r6 \quad (8)$$

Calculation of external components of FAL from FA with normally open contacts differs from the above method. The total resistance of the FAL in case of their operation is always less than the value of the resistance of the terminal resistor of the loop (Fig. 6). An equivalent electrical diagram of the FAL with smoke detectors is shown in Fig. 13.

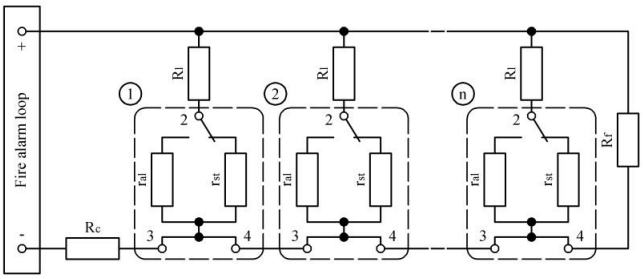

Figure 11. Equivalent electrical circuit of the FAL with normally-open smoke FA r_{st}-resistance of the FA in standby mode; r_{al}-resistance of the FA in alarm mode

The resistance R_l determines the threshold of the IIS and the type of FAL operation mode (single - or two-threshold). In standby mode, the FA resistance is very small relative to the R_f value of the terminal resistor and the FAL resistance value is within r3...r4 of the "Standby mode " range. Smoke detectors installed in the FAL measure the state of smoke in the environment and, in the event of detection of primary signs of fire, change their resistance abruptly. In this case, two series-connected R_1 + r_{al} supports are added to the FA resistance value of the end resistor in parallel. The equivalent electrical circuit of the SHPS when two SPS are triggered is shown in Fig. 14.

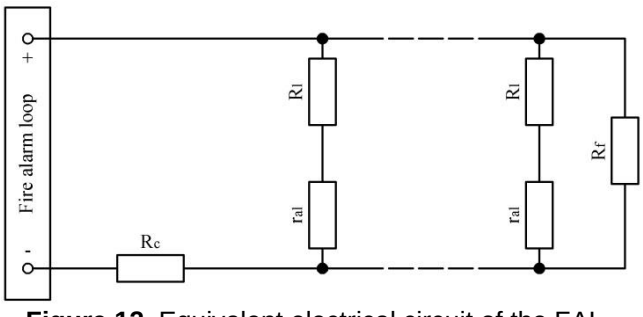

Figure 12. Equivalent electrical circuit of the FAL when two smoke FA with normally open contacts are triggered

To verify for two FA, the following conditions must be met in turn:

$$\frac{1}{r2} < \frac{1}{R_l + r_{al}} + \frac{1}{R_f} + R_c < \frac{1}{r3} \quad (9)$$

$$\frac{1}{r1} < 2\frac{1}{R_l + r_{al}} + \frac{1}{R_f} + R_c < \frac{1}{r2} \quad (10)$$

As the maximum allowable linear resistance of R_c FAL conductors is a fairly small value, and the FAL resistance in the corresponding state of the FACIE must be in the average value of this range, then the inequality (9) and (10) can be simplified and go to the equation, from which the nominal load resistance R_l will be determined in the future:

$$\frac{1}{R_l + r_{al}} + \frac{1}{R_f} = \frac{1}{\frac{r3 + r2}{2}} \quad (11)$$

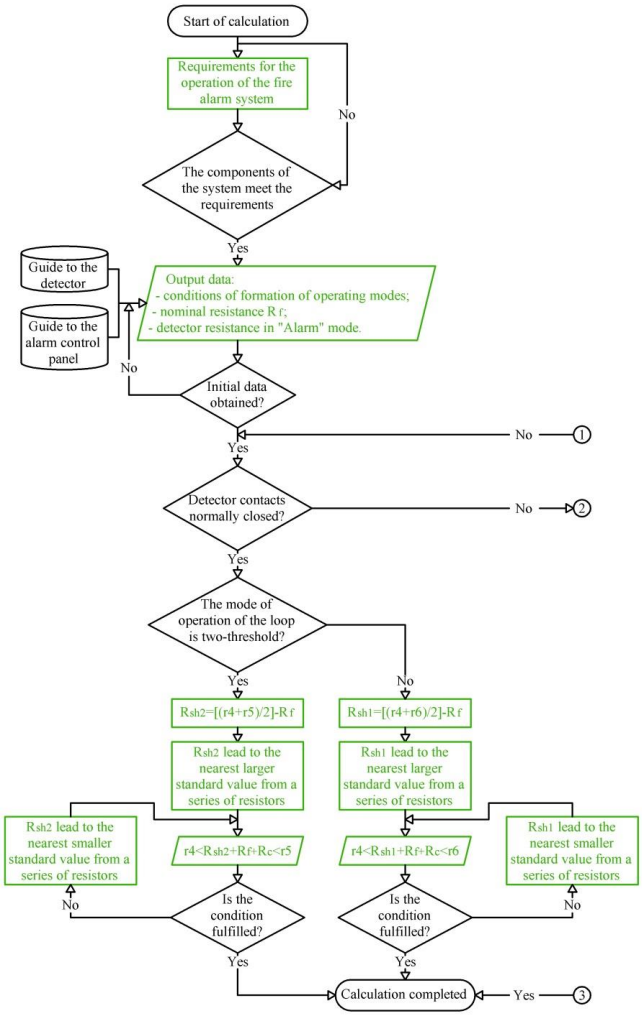

Figure 13. An algorithm for calculation of external components of FAL (beginning)

If we assume that $(r3+r2)/2=r_{av}(r2-r3)$, and transform equation (11), we get:

$$R_l = \frac{r_{av(r2-r3)} R_f}{r_{av(r2-r3)} + R_f} - r_{al} \quad (12)$$

The load resistance value determined from the following relationship corresponds to the single threshold mode of the FAL operation:

$$\frac{1}{r1} = \frac{1}{R_f + r_{al}} + \frac{1}{R_c} + R_c < \frac{1}{r3} \quad (13)$$

Consequently:

$$R_l = \frac{r_{av(r1-r3)} R_f}{r_{av(r1-r3)} + R_f} - r_{al} \quad (14)$$

The algorithm shown in Fig. 15 and Fig. 16 has been developed based on the illuminated method of calculating the nominal value of FAL attachments.

Since each FA has its own internal resistance, in order to balance the FAL with the corresponding modes of operation of the FACIE, it is necessary to take into account the maximum number of them that can be included in the FAL. In the case when the FAL, due to a large number of FA with normally closed contacts, activates the "Attention" mode (see Fig. 11), the following condition is met by the FACIE:

$$R_f + N_{max} R_{sh} < \frac{r4 + r5}{2} \quad (15)$$

where N_{max} – maximum number of detectors with normally closed contacts.

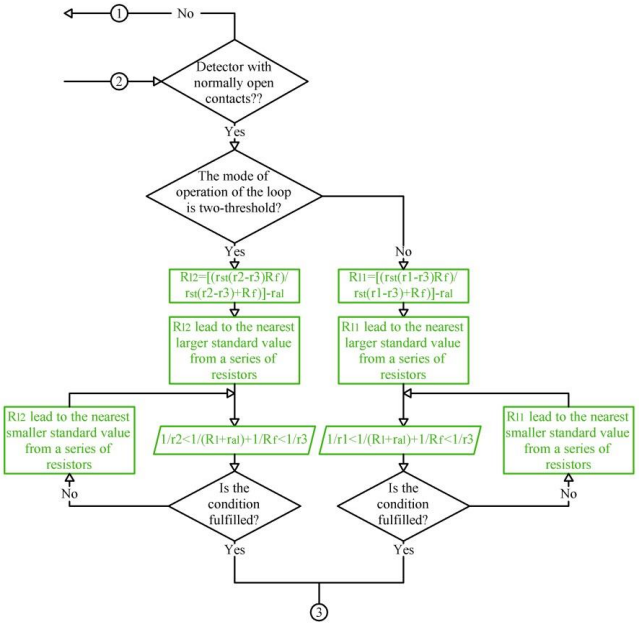

Figure 14. An algorithm for calculation of external components of FAL (continuation)

From here, following the following equation, you can determine the maximum number of N_{max} detectors with normally closed contacts:

$$N_{max} = \frac{\frac{r4 + r5}{2} - R_f}{R_{sh}} - 1 \quad (16)$$

In another case, when the FAL is built on a FA with normally open contacts, if the FA is removed from its base, the "Fault" mode is activated (see Fig. 11) of the

FACIE, since the total resistance of the FAL increases abruptly. An increase in the number of FA in the FAL leads to a shift of the working point of the mentioned mode in the direction of the "Fire" mode. In order to avoid entering the FAL in "Fire" mode, for the corresponding number of FA, when removing one FA from the database, the following condition must be met:

$$\frac{R_l + R_c}{N_{max}} > r6 \quad (17)$$

$$N_{max} = \frac{R_l + R_c}{r6} - 1 \quad (18)$$

The resulting N_{max} value from (18) will provide, in the case of removing the FA with normally open contacts from the base, an indication of the FACIE state of the FAL as "Fault".

5. Conclusions

Analysis of technical documentation of non-address fire alarm control and indicating equipment and FA from different manufacturers allowed to install the entire range of resistance that can FAL make, and obtain a generalized nomogram as the basis for determining the necessary conditions and the conclusion of the relevant equations for determining the denomination of the external elements of the FAL, the use of which will ensure the reliability of functioning of the FAS.

It is established that in the case of using FA with normally closed contacts, two conditions (2) and (3) must be met for the correct functioning of a FAL with verification for two FA, and their values of mounted elements can be determined by (5) and (7).

The calculation of FAL external attachments from different manufacturers with normally open contacts must be performed using (12) and (14), and the values obtained must meet the conditions (9), (10) and (13). The total resistance of the FAL in case of their operation will always be less than the value of the resistance of the terminal resistor of the loop. Since each FA has its own internal resistance, to balance the FAL for the respective operation modes of FACIE must be considered and as many as possible that can be included in FAL in (16) and (18). The results obtained will allow us to design a non-desalinated threshold FAL using equipment from various manufacturers, which will provide informative reliability during operation.

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